# LABORATORY TEST EQUIPMENT

## Goniometer

Testing of crossing signals and wayside signals requires that measurements of light intensity and chromaticity be taken at various angles likely to be encountered by train crews and drivers. The ITE specification has 44 required test points, ranging from 27.5° left and right of the vertical axis, and from 2.5° to 17.5° down from the horizontal axis, as shown in Figure 3. The proposed TC specification has test points that range from 30° left and right of the vertical axis, and 0° to 20° down from the horizontal axis. Both specifications use 5-degree intervals between test points. As discussed at the AREMA committee meetings, an on-axis measurement of light output was added to the TC test pattern.

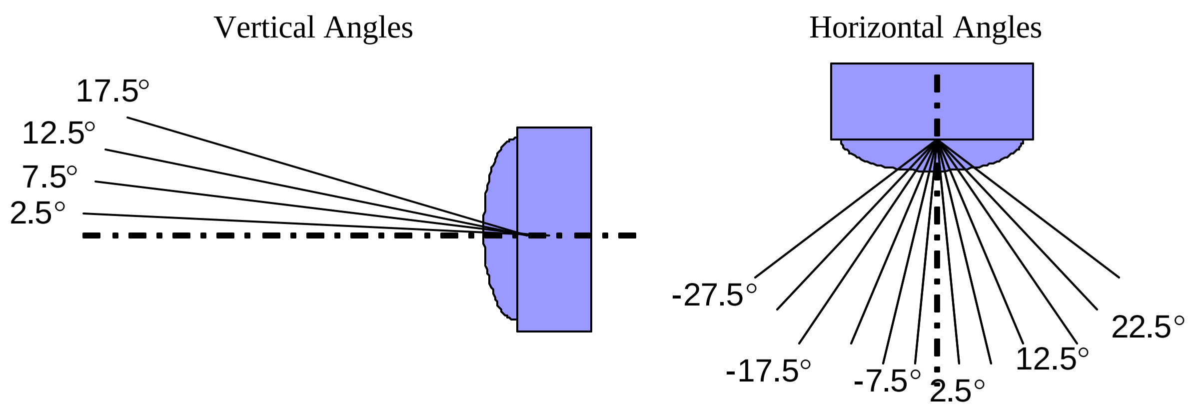


*Figure 3. ITE-style test angles.*

The number of test points per test, the number of signals to test, and the number of possible failure modes of each signal were all reasons to design and build an automated goniometer that could quickly and repeatedly orient the signals to specified angles. A goniometer is a device used to adjust the angular orientation of a test item. The goniometer used in this research can adjust the angle of a signal about both the horizontal and vertical axes.

The goniometer designed and built for this research is shown in Figure 4. It has an aluminum base and frame. A stepper motor and a 30:1 Tsubakimoto Emerson gearbox, model TM10E, are bolted to the middle of the base plate. This stepper motor controls the movement about the vertical axis of the goniometer. The power supply and drivers for the stepper motors are also located on the base plate.

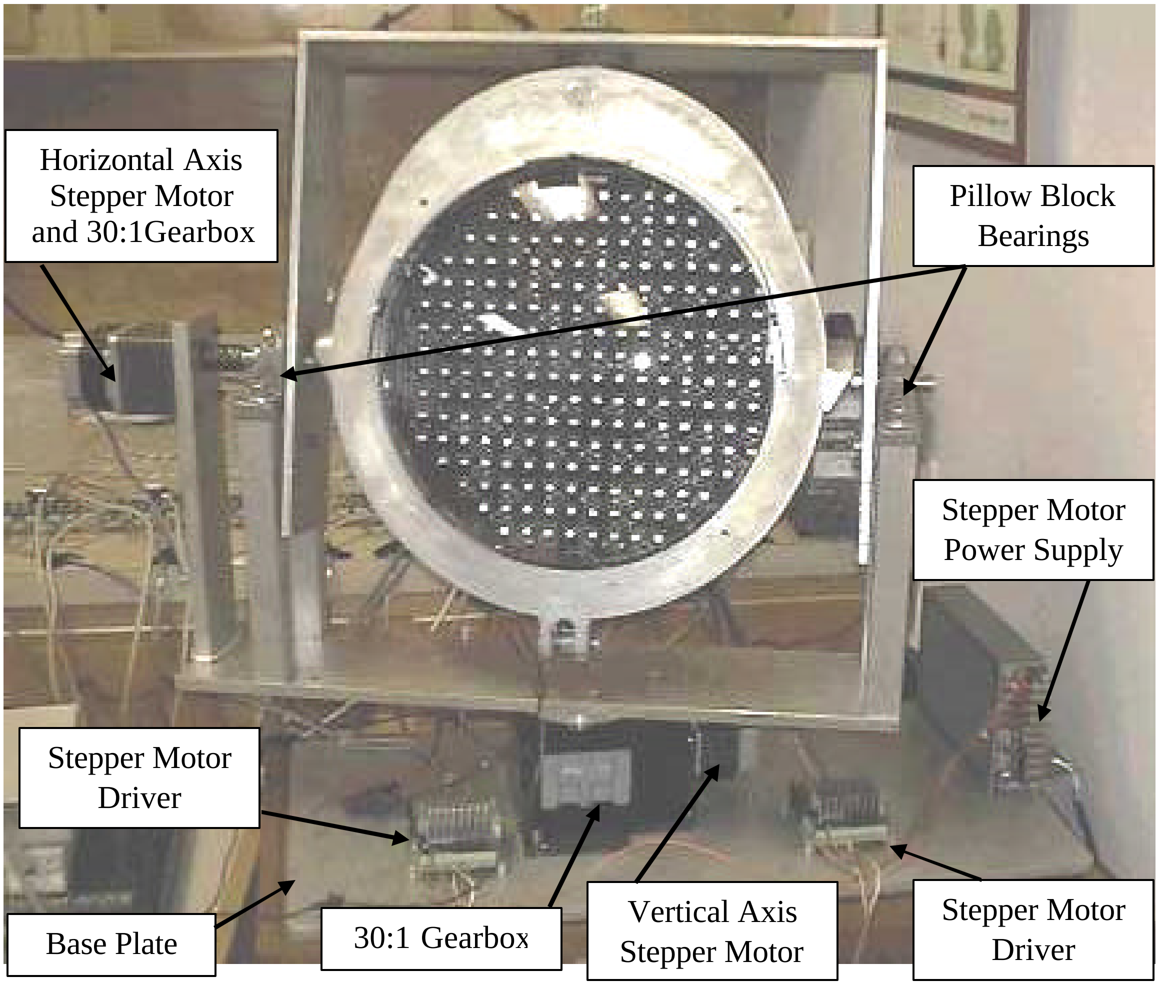


*Figure 4. Goniometer.*

Attached to the output shaft of the vertical axis gearbox is a hub and another horizontal plate, which supports the horizontal axis components of the goniometer. Two sets of aluminum posts are located near the ends of the horizontal plate. Pillow block bearings bolted on the top of these posts support the horizontal axis of the goniometer. The mounting plate for the horizontal axis stepper motor and gearbox is bolted on the end of the horizontal plate near one set of support posts. The horizontal axis stepper motor/gearbox combination is bolted at the top of this mounting plate, in line with horizontal axis. Two shafts are secured in the pillow block bearings with setscrews. The output shaft of the 30:1 gearbox is coupled to one of these shafts. A three-sided frame for holding the signal is attached to these shafts. Two parts of the frame extend up from the shafts, and the top part of the frame is bolted to the ends of the other two parts. A standard signal head is attached to the frame.

The Vexta Stepper Motor model PK566NAWA was selected for moving the goniometer in the vertical axis, and a Vexta Model PK564NAWA-T30 was selected for moving the goniometer in the horizontal axis. These stepper motors have a step size of 0.72 °/step, or 500 steps per revolution. A finer resolution of 0.024 °/step, or 15,000 steps per revolution, is achieved by running each motor through a 30:1 gearbox. Gearboxes improve accuracy in positioning the goniometer to the desired orientation and allow the stepper motors to easily move the goniometer. This ensures that no steps will be skipped, which is important for precision placement in an open loop system. The calculated minimum amount of time for the stepper motor to move the goniometer/signal combination 5° is 0.105 seconds, or about one-tenth of a second. To minimize the strain on the motor, and better ensure precision in moving the goniometer, the stepper motors are operated at a maximum acceleration of 1.68 rad/sec$^2$ (4000 steps/sec$^2$), and a maximum velocity of 4.19 rad/sec (10,000 steps/sec), which results in a five degree move time of 0.50 seconds. These restrictions are applied by the National Instruments motion control board PCI-7344 used to control the stepper motors.

The stepper motors each require 1.4 amps at 24 volts DC. The power supply is a Nemic Lambda model HR-10-24, which can provide an output current of 3 amps at 24 volts to the stepper motors.

Colorimeter

A colorimeter is used to measure the light intensity and color coordinates of the safety signal. A Minolta Chroma Meter, model CS-100A, was selected for this task. This colorimeter has a one-degree acceptance angle, which allows accurate measurement of the safety signal without including ambient light from the test area. The colorimeter can be controlled by a computer via an RS-232 link. The computer can receive measurements from the colorimeter. The luminance data sent by the colorimeter is in units of candela per square meter, and the “x” and “y” color coordinates are sent as unitless, decimal values. The Minolta CS-100A colorimeter uses three silicon photocells to match the spectral response of the CIE Standard Observer. For the “Fast” response setting used in this research, the colorimeter has a range from 0.01 to 299,000 cd/m$^2$, with an accuracy of ±2% of reading, ±1 of the third significant digit. Chromaticity values are accurate to within ±0.004 (Minolta, Instruction Manual, n.d.). The Minolta CS-100A is shown in Figure 5.

*Figure 5. Minolta CS-100A Colorimeter.*

Programmable Power Supply

The LED signals were powered by a Hewlett-Packard 6038A power supply. This programmable power supply can control the voltage supplied to the signal and can communicate with a computer via general purpose interface board (GPIB). The computer sets the desired voltage and current limit to be supplied to the signal. The programmable power supply can also tell the computer the actual voltage output and the actual current draw. The supplied voltage remains at the specified setting, even if the load is changed by enabling or disabling LED elements in the signal. A National Instruments PCI-GPIB card was installed in the computer to communicate with the power supply.

Data Acquisition

The National Instruments DAQPad 6020E, seen in ***Figure*** , has analog and digital IO capabilities. One of its digital lines is used to switch the signal relay, turning the signal on and off, as needed. This allows the testing programs to mimic the partial duty cycle experienced by crossing signals in the field. The analog channels could be used to measure voltage and current supplied to the signal. However, the programmable power supply is used to measure this data, so the analog channels were not used during testing (National Instruments, DAQPad 6020E, 1998).


*Figure 6. DAQPad 6020E.*

Motion Control Board

A National Instruments Motion Control Board PCI-7344 was used for stepper motor control. This board enables National Instruments software, such as LabView and Measurement and Automation Explorer, to set operational limits, such as maximum velocity and maximum acceleration. For signal tests, a trapezoidal motion profile is sent to the motion control board. The trapezoidal profile enables smooth, fast movement of the goniometer. The board outputs step and direction signals to the stepper motor drivers according to this profile (National Instruments, Motion Control, 2001).

Testing Procedure

Tests on the signals were run by placing the signal in the goniometer, aligning the signal with the colorimeter, setting the parameters, running the LabView testing program, saving the data, and resetting parameters for additional tests. LED signal retrofit kits allow for easy replacement of incandescent signals. The hardware used to hold the lens and parabolic reflector of the incandescent signal secures the LED signal in the housing. Installation procedures for an LED retrofit kit vary from brand to brand, so the manufacturer-provided installation instructions were followed for each kit.

Power wires were run through a hole near the bottom of the signal, and the LED relay switch wires were run through the top of the signal, as indicated in ***Figure*** 7. The nuts holding the signal head to the frame were checked and tightened to prevent the signal head from shifting around during a test.

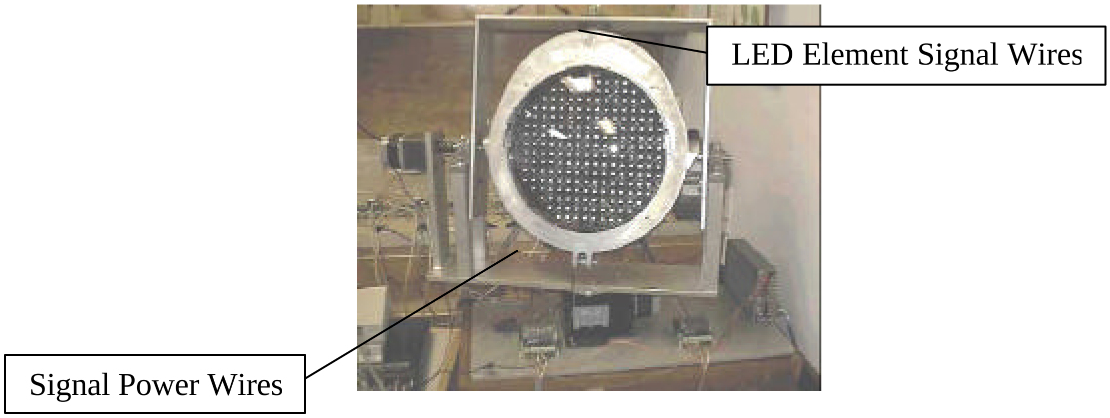


*Figure 7. Layout of Signal and Power Wires for Test Signal.*

The signal must be properly aligned with the colorimeter. The colorimeter is placed approximately 57.3 feet away from the signal. As shown in Figure 8 this allows the one-degree acceptance angle of the colorimeter to measure the entire 12-inch diameter signal. The colorimeter is positioned on the tripod such that the entire signal is inside the viewing circle.

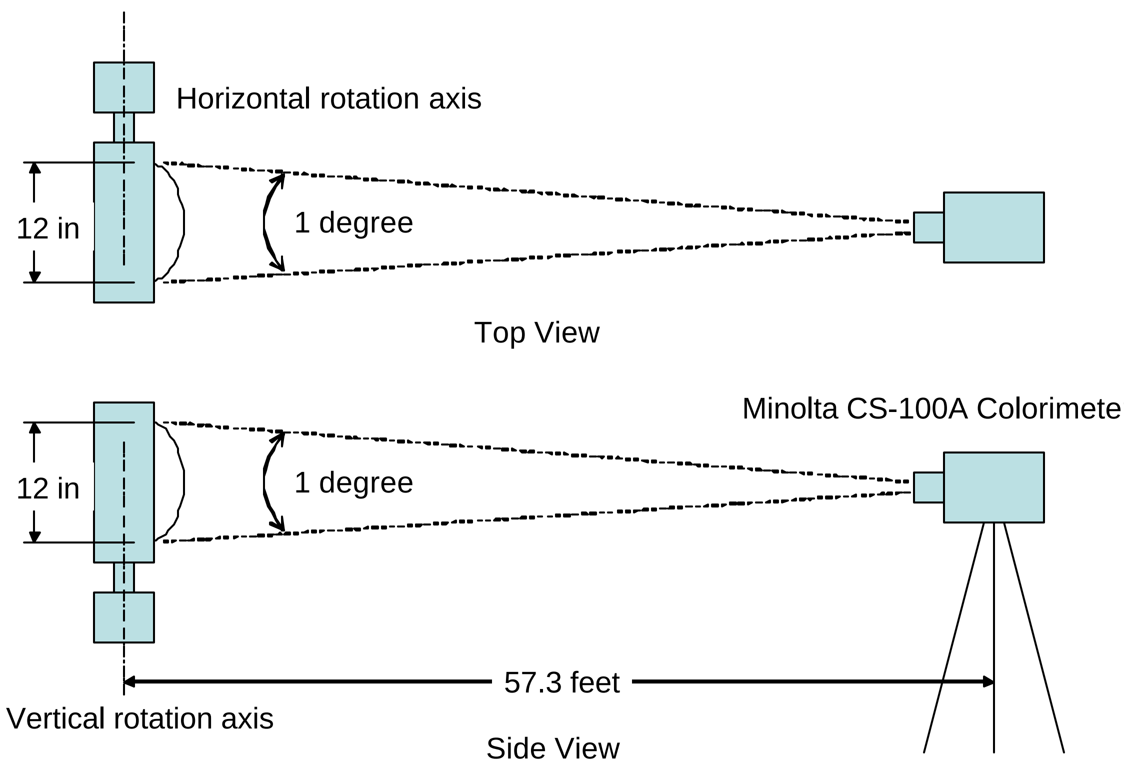


*Figure 8. Layout of Test Setup for 12 Inch Signals.*

A torpedo laser level was used to align the goniometer with the signal. The laser level bracket was screwed onto the lower right bolt on the face of the signal, as seen in Figure 9. The bracket was twisted until it fit tightly against the face of the signal to ensure it was orthogonal to the signal. The torpedo level was placed in the notch of the bracket, with the laser end pointing toward the colorimeter. A ¼-20 x 1-inch bolt secures the level to the bracket. The laser is turned on by pressing the push button at the end of the level opposite the laser.

A “Jog Motors” program is used to align the signal with the colorimeter. The goniometer is positioned such that the laser points at a cardboard target attached to the colorimeter. This target, seen in ***Figure*** 10, is in the same location with respect to the

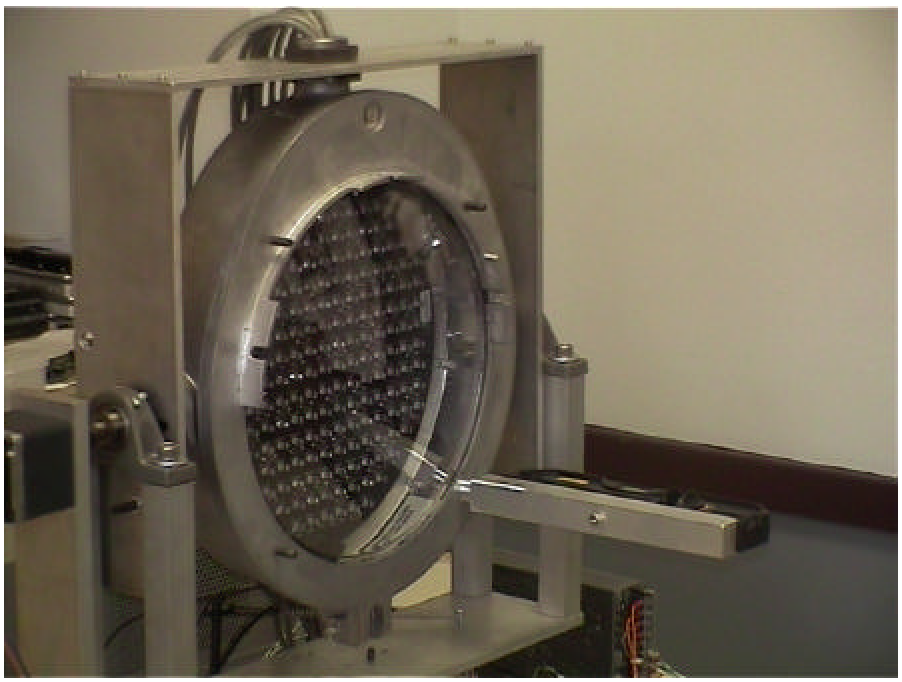

*Figure 9. Positioning the Laser Torpedo Level on the Goniometer*

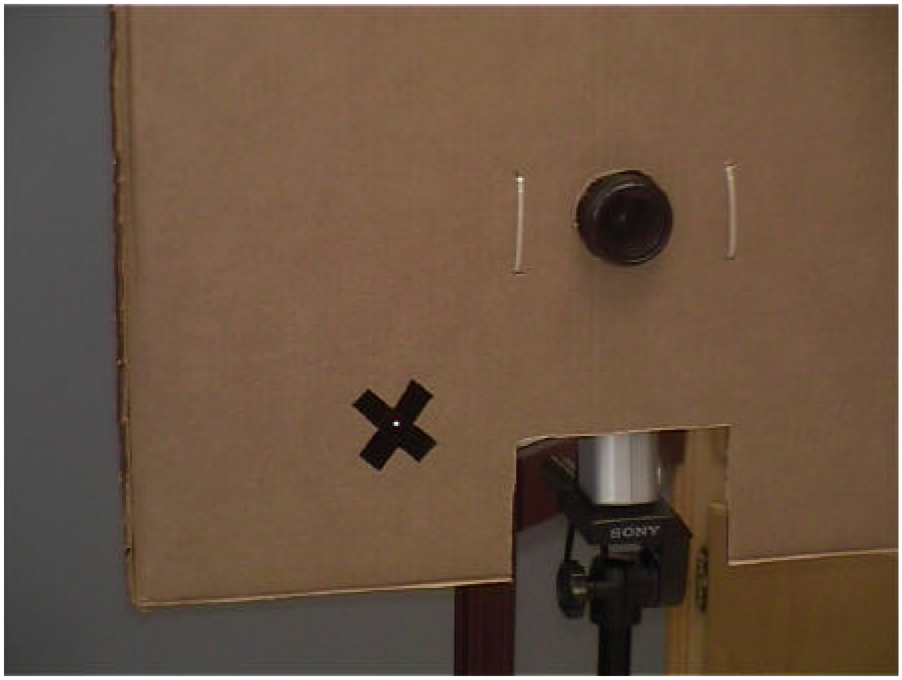


*Figure 10. Aiming the Goniometer at the Colorimeter.*

center of the colorimeter lens as the torpedo level is to the center of the signal. Now the signal is pointed directly at the colorimeter. The torpedo level and bracket are then carefully removed from the signal face.

Rule four of section 11.03 of the ITE standard specifies an alignment tolerance of ±0.25°. Over a distance of about 57.3 feet, the laser must point to a six-inch diameter circle centered at the target to meet this tolerance requirement. The accuracy of the IntelliPoint Plus Laser Torpedo Level is ¼-inch at 100 feet (Stanley, 1998).

Determining the Distance Between Goniometer and Colorimeter

LED signals are comprised of an array of LEDs, so a virtual point source must be determined to accurately calculate luminous intensity. The location of a virtual point source can be found with two irradiance (cd/m$^2$) measurements taken at known distances from an intermediate reference point (Ryer, 1997). These distances ($d_1$ and $d_2$) and irradiance measurements ($E_1$ and $E_2$) can be used with the equation below to find the offset of the reference point to the virtual point source.

$$X = \frac{d_1\sqrt{\frac{E_1}{E_2}} - d_2}{1 - \sqrt{\frac{E_1}{E_2}}}$$

For example, the irradiance at 57 feet away from the signal was measured at 6405 cd/m$^2$, and the irradiance at 59 feet was 5840 cd/m$^2$. With the reference point located at the signal, calculation of Equation 9 results in an offset of –14.7 feet. Therefore, if measurements are taken at a distance of 57 feet away from the signal, the virtual point source is 42.3 feet away from the colorimeter. <u>This virtual point source correction factor was used for all data taken from the 12 inch red LED crossing signals.</u>